CEMENT AND LIME MANUFACTURE

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Research on Cement and Lime.

SOME account of the work on cement and lime being carried out at the Building Research Station is given in the annual report of the Building Research Board for the year 1938, published last month. The report is obtainable from H.M. Stationery Office, price 3s. 6d.

It is stated that during the year under review arrangements have been completed for a large-scale investigation, in co-operation with the Institution of Civil Engineers, on the deterioration of concrete in soils and ground-waters containing sulphate salts. This investigation, which will include field tests extending over a period of ten years, is designed to afford information as to the type and quality of concrete, or the protective measures, which are required to afford satisfactory service under conditions of varying degrees of severity. A preliminary examination has been made of various sites throughout the country in order to select suitable areas in which to lay the concrete test specimens.

Fineness of Cement.

Considerable attention has been paid to the examination of methods for the determination of the fineness of cements, both as part of the general work of the Station and of investigations made in conjunction with the British Joint Committee on Special Cements. The investigation on the effect of changes in the physical condition of Portland cement clinker on the properties of the resultant cements has been completed, but certain more general work on the microscopic study of the structure of the clinker is being continued.

Constitution of Cement.

In the manufacture of Portland cement the raw materials are heated to a temperature at which 20 to 30 per cent. of the mix passes into the liquid state. During the subsequent cooling this liquid portion may solidify as a crystalline

product or become supercooled and form, partially or completely, a glass. It was considered that such variations might produce appreciable differences between the properties of otherwise identical cements, and an investigation was commenced. The original programme of this work has now been completed and, though there is scope for further investigation, the general conclusions reached may be summarised.

The work has comprised the preparation of clinkers in the laboratory under heating conditions so controlled as to produce crystalline or glassy products as required, and the testing of the properties of the resulting ground cements. Apart from the presence or otherwise of the glassy phase, there are many other variables which may affect the properties of the cements, for example, the fineness of grinding, the content of gypsum added to control setting, etc. The programme involved only two basic compositions for laboratory-made cements and two works clinkers, but in view of the variables that have to be taken into account it was necessary to test some 30 samples in full as well as to carry out a limited programme on others.

Since only small samples were available, small-scale methods of test were devised for setting time, soundness, strength, resistance to chemical attack and shrinkage. The method devised for the last of these has been published.[1] In one case a large sample was available which was tested on the full scale for the properties mentioned and also for heat of hydration. The differences in material of the same composition when the full possible amount of the glassy phase was present and when none of the glassy phase was present, i.e. when the cement was completely crystalline, are :

(1) The crystalline clinkers were easier to grind in the small-scale mills. It is, however, uncertain whether this holds under commercial conditions of grinding as some evidence to the contrary has been reported.

(2) There was no difficulty in controlling the setting time of glassy cements, whereas some trouble was experienced with crystalline cements. In the latter case it was often found that the cements stiffened shortly after mixing with water and that to avoid stiffening and to produce normal setting it was necessary to use lime water instead of ordinary water for mixing.

(3) The crystalline cements developed less heat on hydration. This was to be expected on theoretical grounds.

(4) The glassy cements gave somewhat higher strengths at an age of 28 days (the ages tested were 1, 3, 7 and 28 days).

(5) There was some limited evidence that the drying shrinkage of glassy cements may be lower than that of crystalline cements.

(6) The glassy cements had a considerably higher resistance to attack by sulphate solutions than the crystalline cements.

The greatest difference was in the resistance to attack by sulphate solutions, and this may be the most important commercially.

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[1] NURSE, R. W. Determination of the Drying Shrinkage of Mortars: a Small Scale Method, *J. Soc. Chem. Ind.*, 1939, 58, 37-8.

The examination of polished sections of cement clinker by reflected light under the microscope has been used with the clinkers prepared for the work described. An improvement in surface polishing has been obtained by altering the method to that of slow grinding on a machine similar to that described by Phillips.[2] Further attention has been directed to the question of the identification of glass in the matrix surrounding the silicate crystals. This matrix may contain one or more of the following : $3CaO . Al_2O_3$, $4CaO . Al_2O_3 . Fe_2O_3$, and glass (neglecting other minor constituents). When polished specimens are etched with water followed by nitric acid in alcohol, the matrix often shows two constituents, one etched to a grey colour, the other not etched. It has been shown that when the clinkers are annealed in such a way that the matrix must contain $3CaO . Al_2O_3$ and $4CaO . Al_2O_3 . Fe_2O_3$ the former becomes grey on etching and the latter is unetched. Further investigation has shown that when glass is also present it may or may not be etched, depending on its composition. The inference drawn from the tests made is that glasses deficient in Fe_2O_3 are etched while those containing more Fe_2O_3 are not etched, but the limiting content of Fe_2O_3 has not yet been determined. When examining clinkers by the reflected-light method it is possible to identify the silicate minerals positively, but as regards the matrix, if it shows an etch differentiation, it is at present only possible to identify the grey material as $3CaO . Al_2O_3$ or glass, and the white material as $4CaO . Al_2O_3 . Fe_2O_3$ or glass. Sometimes a further identification may be achieved by using polished thin sections for examination by both reflected and transmitted light, the latter occasionally showing a positive identification of $4CaO . Al_2O_3 . Fe_2O_3$.

One of the etch reagents mentioned in the last report as being specific for $2CaO . SiO_2$ was hydrofluoric acid vapour, which etches the silicate to a blue or red colour, depending on the etching time. For record purposes, successful use has been made of colour photography in this case, this being necessary because the specimens cannot easily be stored permanently.

The Constituent Compounds of Set Cements.

The Station has co-operated in an investigation carried out by the American Society for Testing Materials on methods for determination of free lime in cement and cement clinker. Samples differing in type and free lime content were tested by various specified procedures at a number of co-operating laboratories. A summary of the results of the tests, which has been distributed by the committee responsible, shows a reasonable uniformity both between different methods and between different laboratories, and demonstrates the great improvement in this rather difficult analytical determination which has been made during the past few years. The investigation has also proved useful in bringing out a number of minor sources of error in the different methods used.

Investigations on other aspects of the hydration of cement have been limited mainly to the study of the calcium sulphoaluminates which may be formed during

[2] PHILLIPS, F. C. A Universal Ore-polishing Machine. *Miner. Mag.*, 1937, 24 (158), 595-600.

the setting of Portland cement or as a result of the action of sulphate waters on concrete. Two forms, containing different amounts of calcium sulphate, are known, the high sulphate form being generally held to be responsible for the disintegration of Portland cement concrete in sulphate waters. In order to obtain precise knowledge of the conditions of formation of the calcium sulpho-aluminates, attention has been given during the past year to a study at 25 deg. C. of the aqueous quaternary system lime—alumina—calcium sulphate—aluminium sulphate, considered as a reciprocal salt pair. The work is now nearly completed. In the ternary system lime—alumina—water, hydrated di-calcium aluminate occurs as a metastable phase, and cubic hydrated tricalcium aluminate as a stable phase, though the former may persist for a considerable time. These compounds give rise to corresponding metastable and stable equilibria in the present quaternary system. Only the high sulphate form of calcium sulpho-aluminate appears to be formed as a stable phase at 25 deg. C. It has been found that the high sulphate form when shaken in water at 100 deg. C. is partially converted to the low sulphate form. The latter therefore appears to be stable within certain limits of concentration above room temperature and it is also known that it is stabilised at normal temperatures by the presence of alkali hydroxides.

Special Cements.

Work in conjunction with the British Joint Committee on Special Cements has been mainly concerned with the provision of data required for the draft specification for low-heat cements which this committee has under consideration. An officer of the Station attended, as the representative of the British committee, a meeting of the International Committee on Special Cements held in Vienna in August 1938. A series of comparative tests on the surface area and particle-size distribution of Portland cements has been made in collaboration with other members of the International Committee. Cement samples were distributed from the Station to the collaborating laboratories and the results collated. A report on the tests has been submitted through the British Joint Committee to the International Committee on Special Cements and has also been published.[3]

The results of the investigations carried out on the relative resistance of different cements to leaching by pure natural waters are in course of publication as a Building Research Technical Paper.

Tests have been made during the year on a low-heat Portland cement made by a British manufacturer. The cement showed a heat of hydration well below the maximum considered desirable.

Fineness of Portland Cement.

The Wagner turbidimeter for the determination of the surface area of cement has been in constant use and as a result of this greater experience it has been possible to undertake a systematic examination of the various stages of the determination in an attempt to eliminate errors.

[3] See page 150 of this number.

By the recognised Wagner method it is necessary to measure the residue on a U.S. No. 300 sieve, the residue being obtained by washing with water through perforated jets at a specified pressure. A somewhat simpler method for practice in this country has been developed in which a B.S. No. 200 sieve is used, and the cement is washed through the sieve with a definite volume of kerosene from a wash bottle. The separation effected in this way is at a different particle size than in the original Wagner method, but this can be readily corrected for in the formula for calculating the specific surface.

Errors in the method as a whole have been found to arise mainly in carrying out the dispersion of the cement in kerosene as a preliminary to measuring the opacity of the suspension. Improvements in this stage have been effected in two ways. The cement is first mixed with a small quantity of kerosene and oleic acid and " rubbed out " on a porcelain tile, after the fashion used for dispersing pigments. It is then mixed with more kerosene in the tank in which the subsequent opacity measurement is to be made and rotated on a rotary shaker. After shaking it is placed in the apparatus for measuring opacity and the measurements made in the usual way. Results obtained by various observers have been found to be more uniform when this modification is used. An account of the work has been published.[4]

Limes.

It is customary to divide hydraulic lime into two classes, namely, (*a*) moderately or semi-hydraulic limes, and (*b*) eminently hydraulic limes. The development of a standard strength test for moderately hydraulic limes has been under investigation for some time in connection with the proposed British Standard Specification. Eminently hydraulic limes had not been taken into account in this connection until recently, but the question of a standard strength test for such limes is now under attention.

One of the difficulties that has arisen is that of differentiating between these two classes of limes. The results of strength tests on them show considerable overlapping, and, in fact, enquiries have failed to establish any unanimity as to the properties which distinguish eminently hydraulic limes from (i) Portland cement, (ii) non-hydraulic lime and Portland cement mixes, (iii) moderately hydraulic limes.

In connection with the work on the specification for eminently hydraulic limes, a number of tests has been carried out on representative samples. The work includes an investigation into a suitable standard method of slaking for laboratory tests. In some cases, steam slaking at atmospheric pressure has been found to yield the best results in the laboratory, in close analogy with the traditional dry slaking in a sand-covered pile on the building site. An examination is also being made of the temperature coefficient of rate of hardening of the mortar, which is a practical point of importance in winter work.

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[4] PARKER, T. W., and NURSE, R. W. Determination of Fineness of Portland Cement. Notes on the Wagner Turbidimeter. *J. Soc. Chem. Ind.*, 1938, **57**, 436-8.

The problem of testing moderately hydraulic limes for hydraulic strength appears now to have found a solution in a test involving simple damp storage of the sanded mortar specimens for 28 days at 25 deg. C., a temperature conveniently obtainable throughout the year in a simple type of thermostatically controlled oven. A fixed water ratio of 65 per cent. on the dry lime has now been adopted. In co-operative tests with several other laboratories the new method was reported to be simple and straightforward, but close control of temperature was found to be essential. Tests are now being carried out on their own limes by manufacturers to check ease of temperature control and general reproducibility over a period.

It may be advisable to draw attention to the considerable variation of the hydraulic strength with the mode of slaking. Thus, a quicklime slaked so as to provide a large putty yield and complete soundness for plastering finishing coat work will show a very definite reduction in sanded strength at, for example, 28 days, compared with a sound dry hydrate from the same lime.

Tests for B.S.S. for Cement.

The British Standard Specification for Portland Cement (No. 12) was last revised in 1931. It was intimated in the foreword to that edition that the question of including compression tests on cement and sand mortar, either in addition to or in substitution for the tensile tests, was being investigated by the Building Research Station. This investigation, which has been carried out during the past few years, has now been completed and a reliable compression test has been evolved.

As a preliminary in the investigations, tensile, compressive, and transverse tests on many thousands of specimens composed of mortars of various proportions, and of different concretes, were made. It was found that one particular form of test—a compression test on a cement and sand mortar—could be relied upon to give a very close index to the strength of concrete. In fact, the strength of the mortar mix, 1 : 3 with 12½ per cent. of its weight of water, was practically identical with that of a 1 : 2 : 4 concrete with a water-cement ratio of 0·60. At the same time an allied investigation showed that the relation between the compressive strength of concrete and the water-cement ratio could be expressed as a family of curves within practical limits of error. It was therefore possible, from a single compressive test on mortar, to predict with reasonable accuracy the strength of concrete of any water-cement ratio. Subsequent tests carried out by various co-operating laboratories showed, however, that the same difficulties of repetition existed with the compression tests as had been experienced with the tensile tests. In view of this the compression test could not be recommended as a satisfactory alternative to the tensile tests until reproducibility had been obtained.

Analysis of the results obtained for tensile and compression tests showed that the discrepancies among results obtained by various laboratories were due mainly to differences in the degree of hand compacting by individual operators. This seemed to point to lines of further work which have since been followed.

In an attempt to eliminate these differences a mortar cube vibration compaction machine was developed. Tests carried out on a large number of cements showed that when a cement and sand mortar of drier consistency (1 : 3 with 10 per cent. of its weight of water) was compacted by vibration the strength obtained could be related to that of concrete in a manner similar to that for the hand-compacted mortar cubes of wetter consistency. That the personal factor had been practically eliminated was evident from the fact that the maximum variation from the mean for ten different laboratories was 3 per cent. when the vibrated mortar tests were carried out at one central laboratory, and only 8 per cent. when the same laboratories repeated the tests at their own laboratories.

The results have been submitted in detail to the British Standards Institution and, in view of the distinct advantage of the vibration compaction method over other methods, it was felt that British Standard Specification No. 12 should be revised to include a compression test clause. In addition it was agreed that rapid-hardening Portland cement should be brought within the scope of the revised edition, and that a new specification for high-alumina cement should be drawn up.

In order that minimum strength values for inclusion in the revised and new specifications could be ascertained, the results obtained for a large number of cements tested at the Station during the past few years have been analysed. The strength values for the following types of test were examined :

(1) Tensile tests carried out in accordance with British Standard Specification No. 12.

(2) Compression tests carried out on 1 : 3 mortars with 12½ per cent. of water ; compacted by hand.

(3) Compression tests carried out on 1 : 3 mortars with 10 per cent. of water ; compacted by vibration.

Fig. 1 shows the relation between the strengths obtained for hand compacted cubes and vibrated mortar cubes. The values plotted represent the average of six specimens tested at each age, and in order to establish the relation over a wide range the strength results up to 28 days have been included. *Fig.* 2 gives the corresponding relation for high-alumina cement. It is possible, from the curve in *Fig.* 1 and the values obtained for cements which failed to pass the British Standard Specification No. 12 tensile test clause, to establish minimum strength values for Portland cement. These values appear to be 1,600 lb. per sq. in. at three days and 2,500 lb. per sq. in. at seven days for normal Portland cement.

Fig. 3 shows the relation between these suggested values and those specified in British Standard Specification No. 12. On this figure are plotted the values obtained for the existing British Standard Specification tensile test against those obtained for the proposed vibration-compacted mortar cube test. Although the points are rather scattered, a representative curve has been drawn, together with enveloping curves within which all values would be expected to lie for Portland cements. As before, the cements failing to pass the British Standard Specification

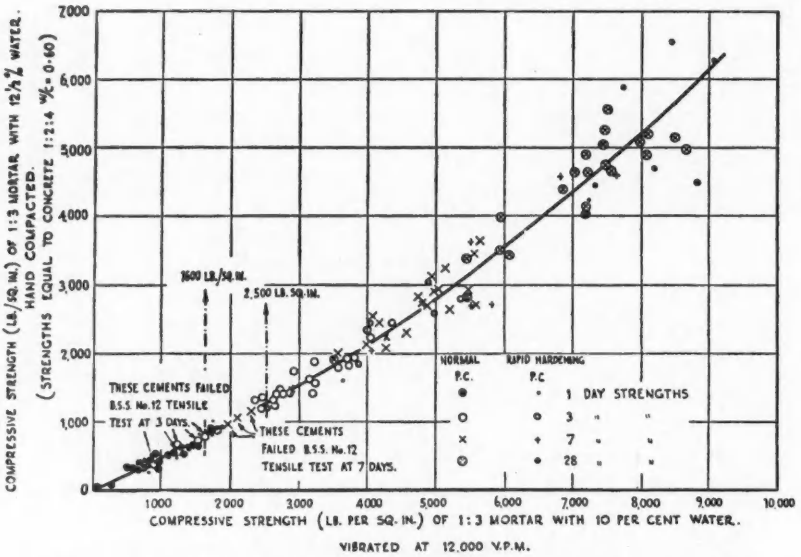


Fig. 1.—Relation between Compressive Strengths of Hand Compacted and Vibrated Mortar.

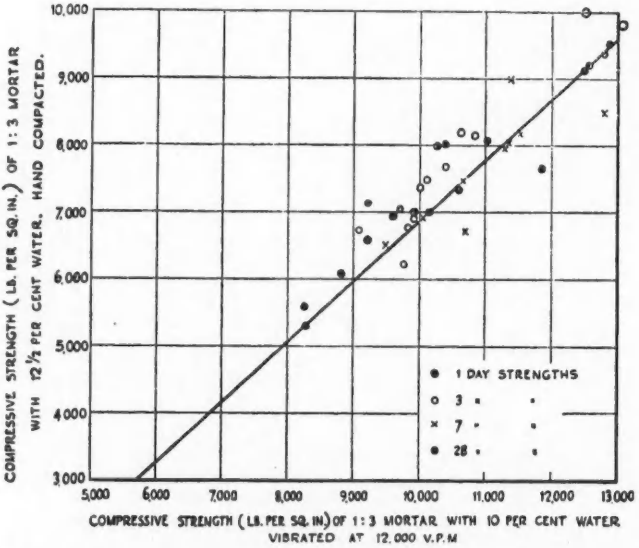


Fig. 2.—Relation between Compressive Strengths of Hand Compacted and Vibrated Mortar for High Alumina Cements.

tensile test clause indicate values for inclusion in the revised specification for vibrated mortar cubes. The values from this curve agree with those derived from *Fig.* 1 for normal Portland cement.

On the basis of this work, the following values would seem to be suitable for inclusion in a compression test clause in the revised and new specifications :

For Normal Portland Cement.—The compressive strength of the vibrated mortar cubes shall not be less than 1,600 lb. per sq. in. at three days (72 hours).

The compressive strength of the vibrated mortar cubes at seven days shall

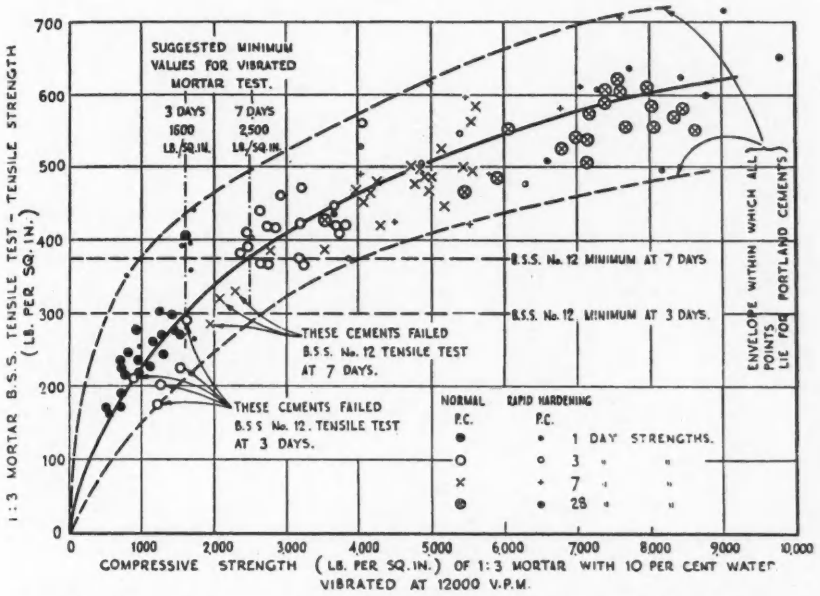


Fig. 3.—Relation between B.S.S. Tensile Test Strength and Vibrated Mortar Compressive Strengths.

show an increase on the strength at three days and shall not be less than 2,500 lb. per sq. in.

For Rapid-Hardening Portland Cement.—Values of 1,600 lb. per sq. in. at one day and 3,500 lb. per sq. in. at three days are suggested.

For High-Alumina Cement.—Values of 6,000 lb. per sq. in. at one day and 7,000 lb. per sq. in. at three days are suggested.

The values to be adopted are, however, under consideration by the British Standards Institution.

Cement for Sealing Oil Wells.

SPECIAL problems exist in connection with the cementing of oil wells. The cement is placed far below the surface of the ground, ranging in depth from several hundred feet to 9,000 ft. or more, and the temperature at the cementing point may be as high as 200 deg. F.

The question of special cements for this work is discussed in a recent number of the Cement Mill Edition of " Concrete," where it is stated that the composition of the cement must be such that a " pumpable " slurry of cement and water can be obtained without the addition of a quantity of water so excessive that it has an adverse effect on the strength and density of the set cement. On this point the specification of the Standard Oil Company of California sets a limit of 40 lb. of water to 100 lb. of dry cement. The slurry must remain fluid, regardless of the agitation and the high temperature to which it is subjected, until it has been pumped down through the well casing to its final resting place. This time may range from a few minutes to two hours, the latter being the approximate maximum time required in the California fields where cementing operations frequently are carried on at depths of 9,000 ft. The slurry, when in place, should set hard quickly and develop sufficient strength to withstand the stresses set up in an oil well. The set cement should be impermeable to water and oil, and form an enduring bond with the casing and with the walls of the hole.

A test has been developed for the purpose of determining, in advance, whether any given brand of cement can be pumped to the bottom of a well before it sets. This equipment is designed on the principle of a motor-driven ice-cream freezer. The space corresponding to the ice-salt compartment of the freezer is a water jacket which can be heated electrically to control the temperature of the slurry. The latter is in a cylindrical container holding about two quarts and corresponding to the can of a freezer. It is fitted with both stationary and revolving paddles, a device for measuring the torque required to mix the slurry, a motor to mix the slurry at constant speed, and means for heating the water jacket. The consistency of the slurry in the cylindrical container is measured by a spring balance connected to the outer edge of the container by a chain. As the rotating paddles stir the slurry, the container has a tendency to rotate with it. Through this tendency to rotate, a pull is exerted on the chain and, therefore, on the spring balance. At first this pull is almost nothing. At the end of the first 30 minutes of mixing, the pull must not exceed 8 ounces. As the slurry slowly stiffens, the pull is increased, and when it has reach 40 ounces the slurry is regarded as being too stiff to pump. This point must be reached in not less than 140 minutes and not more than 180 minutes.

Briquettes for tensile tests are made in two sets. Those intended for test at 70 deg. F. are cured for 24 hours in moist air, and for the remaining time in water

MINIMUM TENSILE STRENGTHS IN LB. PER SQ. IN.

Age of Briquette	Curing temperature	
	70 deg. F.	150 deg. F.
24 hours	100	350
4 days	250	450
28 days	350	500

at 70 deg. These briquettes are removed from the moulds at the end of the first 24 hours. The briquettes intended for testing at 150 deg. F. are submerged immediately in water at 150 deg. F. At the end of four or five hours they are removed from the moulds and immediately returned to the water bath. Thirty minutes before the time for testing they are transferred to the 70-deg. water bath, so as to be cooled to 70 deg. when tested.

Our contemporary states that cement manufacturers may obtain a blueprint of this testing apparatus by writing to the Standard Oil Company of California, 225 Bush Street, San Francisco, California, U.S.A. Other tests required are made with usual cement-testing equipment, as will be seen from the following summary of the requirements of the Standard Oil Company:

(1) All tests shall be made with 40 lb. of water to 100 lb. of dry cement.

(2) Tests shall be made with a sample of 2,000 gr. of cement.

(3) The cement must not contain any unground particles that will not pass the 30-mesh screen.

(4) The 30-minute mixing test shall show a pull of not more than 8 ounces on the spring balance.

(5) The mixing time required to obtain a pull of 40 ounces on the spring balance shall be not less than 140 minutes or more than three hours.

(6) The tensile strength of briquettes at ages of 24 hours, 4 days, and 28 days shall be not less than the values given in the table.

(7) The cement shall pass the A.S.T.M. soundness test.

Edgar Allen & Co., Ltd., & The British Rema Manufacturing Co., Ltd.—Messrs. Edgar Allen & Co., Ltd., have purchased the undertaking and goodwill, including patents and patent rights, of the British Rema Manufacturing Co., Ltd., of Halifax. In association with Messrs. Edgar Allen & Co., Ltd., the British Rema Manufacturing Co., Ltd., will carry on its business in future operating from the works of the Machinery Department of Edgar Allen & Co., Ltd., at the Imperial Steel Works, Sheffield. Mr. P. G. Ryder, Southern Technical Representative of the British Rema Co., Ltd., will have his office at Artillery House, Westminster, S.W.1. The British Rema Manufacturing Co., Ltd., manufacture pulverised fuel plant for cement rotary kilns, boiler and furnace firing, etc., as well as a wide range of machines.

The Fineness of Cements.

THE following paper, entitled " Comparative Tests on the Fineness of Cements," by Dr. F. M. Lea, is reprinted by permission from the *Journal* of the Society of Chemical Industry.

The determination of the fineness of powders below the usual sieve sizes is a problem of importance in many industries and, although the following report comparing results by different methods in various laboratories is concerned only with Portland cement, its conclusions may have a wider field of application. Comparative tests on the surface area and particle size distribution of cements have been carried out by photoelectric sedimentation, pipette sedimentation, and air elutriation methods in a number of laboratories. The agreement between the results, when calculated to a common basis, is promising, the major source of variation seeming to arise in the method of dispersing the powder in the liquid medium.

The International Committee on Special Cements, a sub-committee of the International Commission on Large Dams, has for some years had under consideration the methods required for the testing of low-heat cements. As part of its work arrangements were made for comparative tests on the fineness of cements to be made in a number of different countries, the distribution of the necessary samples being undertaken by the Joint Sub-Committee on Special Cements of the Institution of Civil Engineers and the British Committee on Large Dams. The samples were sent out from the Building Research Station and the results reported have been collated and recalculated where necessary by the present author. The following report is based on one submitted to the International Committee on Special Cements by the British Joint Committee on Special Cements.

The laboratories collaborating in the tests were as follows: France: Société Anonyme des Chaux et Ciments de Lafarge et du Teil, Laboratoire Centrale (Dr. E. Rengade). Germany: Laboratorium des Vereins deutscher Portland-zement Fabrikanten, Berlin-Karlshorst (Dr. G. Haegermann). Great Britain: (1) Associated Portland Cement Manufacturers, Ltd., Research Department, Gravesend, Kent (Mr. D. C. C. Crichton). (2) Building Research Station, Garston, Herts. Sweden: Skanska Cementaktiebolaget, Limhamm (Dr. L. Forsén). U.S.A.: Bureau of Reclamation, Denver, Col. (Mr. J. L. Savage).

Samples of three Portland cements were distributed in sealed glass containers. Two of these cements (A and B) were grey Portland cements, and one (C) a white Portland cement.

The methods employed by the different laboratories were as follows: (1) France, (*a*) Wagner turbidimeter; (*b*) air elutriator. (2) Germany, Andreasen pipette. (3) Great Britain, (*a*) Associated Portland Cement Manufacturers, Ltd., photo-electric turbidimeter; (*b*) Building Research Station, Wagner turbidimeter. (4) Sweden, Andreasen pipette. (5) U.S.A., Wagner turbidimeter. The essential details of the methods are given in the Appendix.

The particle diameters in all cases except No. 3(*a*) were derived from Stokes's law, but whereas in Nos. 1(*a*), 1(*b*), 2, 3(*b*), and 5 the particle diameter was taken as that of the sphere of the same density and falling velocity, in No. 4 it was taken as the Andreasen dimension, namely the side of the cube of the same volume as the Stokes's law sphere. In No. 3(*b*) the particle size diameters depend ultimately on microscopic measurements and are not therefore directly comparable with the others. In the laboratories using the Wagner turbidimeter the surface area was calculated as described by Wagner, the mean particle diameter of the fraction below 7·5 μ. being taken as 3·8 μ., but there was a slight variation in the maximum particle size considered in the surface area calculations; in Nos. 1(*a*) and (5) this was 60 μ. and in No. (3) 70 μ., the variation being due to the different sieves used. This variation has, however, only a negligible effect on the calculated surface area. The surface areas derived from the Andreasen pipette data in the case of No. (4) were calculated in two ways: (i) for particles down to a diameter of 1 μ., the surface area of particles below 1 μ. being neglected; (ii) for all particles down to those of least diameter present (0·4—0·5 μ.), this being done by extrapolation of the particle size–weight distribution curve.

In the case of No. (2) only the particle size–weight distribution curve was reported and in 3(*a*) only the surface area, the method used in this latter case not giving the particle size distribution curve.

The results obtained for the particle size distribution curves and surface area depend on (i) the basis of calculation of the particle size diameter, (ii) the assumption made as to the average diameter of the smallest particle size fraction on which no direct measurement is obtained. They may also be affected by (iii) the method used. The results as reported involve variations in all these three factors and, to enable a direct comparison to be made, the results have all, except in No. 3(*a*) where the particle size distribution curve is not available, been recalculated using a common basis for (i) and (ii). This common basis is that used in the Wagner method, namely the diameter and surface area of a particle are taken as equal to that of the Stokes's law sphere of the same density and falling velocity, and the mean diameter of all particles below 7·5 μ. is taken as 3·8 μ. In the case of laboratory No. 4 the particle size distribution curve was not given above 25 μ.,* and in the recalculation of the data from all the laboratories only particles up to this diameter were therefore considered. The surface area of particles above 25 μ. in diameter is small, less than 100 sq. cm. per gram of cement. The particle size intervals used in the calculation are otherwise the same as in the Wagner method.

The total surface areas as reported, based on various assumptions under (i) and (ii), are shown in *Table* I and the values recalculated to a common basis, as described, in *Table* II. The particle size–weight distribution results, also recalculated to the same common basis, are shown in *Table* III. In the case of laboratories Nos. 1, 2, 3(*b*), and 5 these particle size distribution data do not differ

* This is the Stokes's law sphere diameter. The corresponding Andreasen dimension is 20 μ.

from the results as reported. The data as reported from laboratory No. 4 are given in the Appendix.

TABLE I

Specific surface of cements (sq. cm. per gram) as reported

Laboratory No.	Method	Cement A	Cement B	Cement C
1(*a*)	Wagner	2065	1780	1650
3(*a*)	Photo-electric turbidimeter	1999	1622	1775
3(*b*)	Wagner	2270	1890	1785
4	Andreasen, I	2635	2360	1930
	Andreasen, II	3735	3370	2770
5	Wagner	2221	1803	1689

The results from Laboratory No. 4 were calculated (I) for particles down to 1μ.; (II) for all particles down to the smallest size present (0·4—0·5μ.).

TABLE II

Specific surface of cements (sq. cm. per gram)
Results recalculated to common basis for particles below 25μ. in diameter

Laboratory No.	Method	Cement A	Cement B	Cement C
1(*a*)	Wagner	2005	1735	1620
2	Andreasen	2140	1930	1705
3(*b*)	Wagner	2195	1850	1775
4	Andreasen	2240	2005	1695
5	Wagner	2180	1770	1650
Mean values by Andreasen method ..		2190	1965	1700
Mean values by Wagner method ..		2125	1785	1680
Mean values by both methods		2150	1860	1690

It will be seen from *Table* II that for cements A and B there is a tendency for the Andreasen method to give rather higher results than the Wagner method, but, as the values obtained by the two methods overlap in the case of cement A, it is doubtful if any significance should be attached to this. Duplicate tests in any one laboratory should give values differing by not more than 50 sq. cm. per gram, and the greater range found on comparing the values obtained from different laboratories must be attributed to slight variations in test technique. From work carried out at the Building Research Station it is believed that the major source of variation arises in the dispersion of the cement. The Wagner method of dispersing with a brush rotating in a test-tube at high speed is difficult to standardise and it is considered that a change in this method of dispersion is desirable. It has been found that the method of rubbing the cement to a paste with a limited amount of the liquid medium, as used for the dispersion of pigments, can be more readily standardised and gives slightly higher values for the surface area. A paper on this subject has appeared recently.[1]

The assumption made as to the average diameter of the particles below 7·5 μ. has a very large effect on the surface area calculated, as may be seen by comparing the two different values given in *Table* I for the results obtained in laboratory No. 4.

TABLE III

Particle size distribution. Results recalculated to common basis

Cumulative % by weight

Laboratory No.	1(*a*)	1(*b*)	2	3(*b*)	4	5
			Cement A			
μ.						
60	94·6	94·6	96·1	94·4	—	95·1
55	92·6	—	94·5	92·5	—	93·3
50	90·3	—	92·5	90·7	—	91·0
45	86·6	—	89·7	89·0	—	88·0
40	82·5	—	86·6	86·2	—	84·8
35	77·6	—	81·6	83·0	—	80·1
30	71·7	68·8	75·8	77·5	—	75·2
25	64·3	—	68·4	70·0	69·3	68·9
20	56·5	—	60·1	60·5	61·0	60·6
15	47·0	47·8	49·4	50·4	51·5	50·9
10	34·0	—	37·4	37·4	39·0	37·7
7·5	26·8	—	28·5	30·7	31·8	30·2
			Cement B			
μ.						
60	90·2	90·2	93·4	87·0	—	90·9
55	88·7	—	91·3	85·5	—	89·9
50	85·8	—	89·0	82·7	—	85·9
45	81·5	—	85·8	80·2	—	81·9
40	77·3	—	81·9	78·0	—	77·5
35	70·9	—	76·9	71·5	—	73·2
30	65·0	61·1	71·0	65·1	—	66·6
25	58·0	—	63·2	57·4	61·9	59·3
20	50·4	—	54·8	50·8	54·5	50·6
15	39·6	39·4	44·1	41·6	46·0	40·5
10	27·9	—	31·1	30·1	34·5	28·6
7·5	21·6	—	25·0	24·3	27·5	22·3
			Cement C			
μ.						
60	89·5	89·5	93·6	84·7	—	90·1
55	88·0	—	90·2	83·7	—	88·5
50	84·0	—	86·6	82·8	—	84·5
45	80·1	—	82·2	81·9	—	80·2
40	75·0	—	77·5	78·1	—	76·0
35	68·0	—	71·1	72·0	—	70·4
30	62·5	55·7	65·1	68·5	—	62·7
25	54·8	—	56·2	61·1	54·9	55·8
20	47·0	—	47·1	52·6	47·0	47·4
15	36·7	36·0	36·5	39·0	38·0	36·9
10	25·7	—	25·2	26·9	27·5	26·4
7·5	19·5	—	19·5	20·6	21·5	20·2

Standardisation of particle size by microscopic measurement usually tends to give surface area values which are lower than those obtained when Stokes's law is taken as the basis ; the results from laboratory No. 3(*a*), shown in *Table* I, are in agreement with this apart from cement C. Other results supplied by this laboratory indicate that the value reported for surface area would be about 10 per cent. higher if Stokes's law were substituted for microscopic measurement as the basis of calibration.

The particle size–weight distribution data shown in *Table* III show some variation between different laboratories. It may be noted that while in labora-

tories Nos. 1, 4, and 5 the density of the cements was taken as 3·15, as is common when using the Andreasen or Wagner method, the actual density was determined in laboratories Nos. 2 and 3(*b*). The densities obtained were respectively: cement A, 3·13, 3·15; cement B, 3·12, 3·12; cement C, 3·00, 3·05. Differences in the values assumed for the density have a greater proportionate effect on the particle size distribution curve than on the calculated surface area.

The order of agreement between the surface area and the particle size distribution results obtained in the different co-operating laboratories is very promising and it seems probable that if the method of dispersion can be more closely standardised the reproducibility of results should be high. It is suggested, however, in order that results may be directly comparable, that a common assumption should be made as to the particle size ranges over which the surface area is calculated and of the average particle size of the fraction below 7·5 μ. in diameter.

Appendix: Notes on Methods.

LABORATORY NO. 1. FRANCE

(*a*) *Wagner Turbidimeter.*—Method as described by Wagner.[2] The speed of rotation of the stirring brush used for the dispersion was 3,500 to 4,000 revolutions per minute. Measurements are made to a maximum particle size of 60 μ. (U.S. 325-mesh sieve). Sedimentation medium, kerosene with oleic acid as dispersing agent.

(*b*) *Air Elutriator.*—5-g. sample elutriated for 25 minutes in an air elutriator of the type described by J. C. Pearson and W. H. Sligh.[3] Separation effected at air velocities required by Stokes's law to remove particles below 15 and 30 μ. respectively.

LABORATORY NO. 2. GERMANY

Andreasen Pipette.—Method as described by Andreasen.[4] Sedimentation medium, anhydrous ethyl alcohol containing 3·3 g. of anhydrous calcium chloride per litre. The particle diameter was taken as the diameter of the sphere calculated from Stokes's law and not as the dimension defined by Andreasen which is the side of the cube of the same volume as the Stokes's law sphere. Measurements made over range 10—88 μ.

LABORATORIES NOS. 3(A) AND 3(B). GREAT BRITAIN

(*a*) *Associated Portland Cement Manufacturers, Ltd. Photo-electric Turbidimeter.*—Design of instrument based on Wagner turbidimeter, but only total surface area, and not particle size distribution, determined. Sedimentation medium, normal butyl alcohol. Calibration is based on a standardisation with fractions of small particle size range, the average particle size of which was determined by microscopic measurement.

(*b*) *Building Research Station. Wagner Turbidimeter.*—Method as described by Wagner.[2] The speed of rotation of the stirring brush used for the dispersion was 3,000 revolutions per minute. Measurements were made to a maximum particle size of 70 μ. (British Standard sieve No. 300). Sedimentation medium,

kerosene with oleic acid as dispersing agent. Measurements made in a constant-temperature room (20 deg. C.) and timing burette not used.

LABORATORY NO. 4. SWEDEN

Andreasen Pipette.—Method as described by Andreasen.[4] Sedimentation medium, methyl alcohol saturated with sodium pyrophosphate as dispersing agent. The particle diameter was taken as the Andreasen dimension, i.e. the side of the cube of the same volume as the Stokes's law sphere. Measurements made over range 1—90 μ. The surface areas reported were calculated in two ways: (1) surface area for particles above 1 μ.; (2) surface area for all particles, the lower size limit being found by graphical extrapolation. The particle size-weight distribution data obtained were as follows:

Per cent. weight of particle size*	Cement A	Cement B	Cement C
μ.			
20—90	30·80	38·15	45·20
10—20	23·65	21·35	22·00
5—10	18·25	17·20	14·80
2—5	15·95	13·20	10·75
0·8—2	8·70	7·30	5·05
0·5—0·8	2·65	2·80	2·20

* Andreasen dimensions.

LABORATORY NO. 5. U.S.A.

Wagner Turbidimeter.—Method as described in American Society for Testing Materials Tentative Specification C115—34T.[5]

(1) T. W. Parker and R. W. Nurse, J.S.C.I., 1938, 57, 436.
(2) Proc. Amer. Soc. Test Mat., 1933, 33, II, 553.
(3) Bur. Stand. Tech. Paper 48, 1915.
(4) Kolloid-Z., 1929, 49, 48, 252; Zement, 1930, 19, 698.
(5) Tentative Standards, 1936 399.

PNEUMATIC CONVEYING AND DUST COLLECTION.—Messrs. Davidson & Co., Ltd., of Sirocco Engineering Works, Belfast, have issued a brochure describing and illustrating their "Sirocco" pneumatic conveying equipment, mechanical draught, and flue dust collector installed at the Portobello power station of the Edinburgh Corporation. The brochure is a useful description of modern practice.

Cement Testing in Brazil.

THE method for the mechanical testing of cements adopted by the new Brazilian specifications is described by Eng. Ary F. Torres (Director of the Institute for Technological Research of São Paulo) in a brochure issued by the Institute. The brochure states that in standard tests for the acceptance of Portland cements one of the most important factors is strength. In the early days laboratories were interested primarily in standardising and simplifying all the variables involved so as to obtain comparable data on the properties of different cements. In this way methods for the mechanical mixing and tamping of standard non-plastic earth-moist mortars were established which were very different from the mortars employed in practice, and the standard sand used was ungraded. The specifications for Portland cements in use in several European countries and in the United States still follow to a certain extent these ideas. Each country has its own methods, which differ considerably in several respects, with the result that they yield non-comparable data when testing the same material.

The non-plastic mortars used in these countries do not show the true rate of increase of strength and do not emphasise the superiority of the better cements. Also, they allow only a very small percentage of water, and under these conditions the behaviour of the cement is very different from that in practice, either as mortar or concrete. Hence the methods adopted to date for comparing cements do not allow comparison under conditions similar to those under which the material is used. This fact is recognised by all authorities on the subject.

In Brazil there did not exist any accepted practice based on any particular testing method, so that the authorities were free to adopt methods more in accordance with present-day ideas, and, in 1933, published a method for making the mechanical test. This method has since come into general use throughout the country and in 1938 the Brazilian Federal Government established a national specification for ordinary Portland cement in which the testing method referred to is adopted. In this method the standard mortar is really plastic, and is made with graded sand obtained by mixing equal parts of four different sizes of material. Besides using a fully plastic mortar so that the material will be subjected to a test under conditions similar to those in building practice, the method yields values comparable with those obtained with concretes made with the same water-cement ratio. In Lea and Desch's book, "The Chemistry of Cement and Concrete," the importance of this point is emphasised by the following remarks: "Recent work has shown that, though the tensile or compressive strength of earth-moist 1 : 3 sand mortar with a water content of about 8 per cent. (water-cement ratio 0 · 32) is only poorly related to concrete strength, the strength of a plastic mortar containing 12 · 5 per cent. water (w/c = 0 · 50) shows a much better relationship. This is particularly the case for the mortar compressive strength. It seems likely that the methods for specification strength

TABLE OF COMPARATIVE RESULTS OF THE STRENGTHS OF CONCRETE AND STANDARD MORTAR.

Water Cement l/kg	Mix by weight	Strength in kg/cm²				Strength of mortar in percent of concrete strength				N.° of Test	Brand
		2 days	3 days	7 days	28 days	2 days	3 days	7 days	28 days		
0,500	1:3	—	—	181	313	—	—	98	108	3885	A
	1:1,92:3,08	—	—	185	290	—	—	100	100		
0,483	1:3	—	97	179	305	—	76	88	99	3922	A
	1:2,00:3,00	—	127	204	308	—	100	100	100		
0,510	1:3	—	93	164	293	—	79	96	102	3973	A
	1:1,65:3,35	—	118	170	288	—	100	100	100		
0,470	1:3	—	—	147	231	—	—	88	94	4049	J
	1:1,65:3,35	—	—	167	246	—	—	100	100		
0,475	1:3	—	106	186	287	—	90	110	101	4063	A
	1:1,65:3,35	—	118	170	283	—	100	100	100		
0,487	1:3	—	104	170	281	—	90	96	95	4109	A
	1:1,65:3,35	—	116	178	296	—	100	100	100		
0,487	1:3	—	139	220	315	—	79	94	95	4123	B
	1:1,65:3,35	—	177	235	331	—	100	100	100		
0,480	1:3	—	137	222	329	—	102	99	104	4143	A
	1:1,88:3,12	—	134	225	316	—	100	100	100		
0,500	1:3	—	—	99	183	—	—	93	112	4162	K
	1:1,96:3,04	—	—	106	164	—	—	100	100		
0,480	1:3	—	—	163	255	—	—	94	110	4163	K
	1:1,96:3,04	—	—	174	281	—	—	100	100		
0,487	1:3	—	123	197	309	—	90	94	100	4193	A
	1:1,96:3,04	—	137	209	308	—	100	100	100		
0,480	1:3	—	144	210	313	—	94	100	101	4194	B
	1:1,96:3,04	—	154	210	309	—	100	100	100		
0,500	1:3	—	—	103	172	—	—	108	93	4216	L
	1:1,96:3,04	—	—	95	186	—	—	100	100		
0,487	1:3	101	132	198	301	96	96	93	102	4245	A
	1:1,96:3,04	105	138	214	304	100	100	100	100		
0,487	1:3	142	165	246	377	120	103	106	125	4306	A
	1:1,86:3,14	218	161	233	301	100	100	100	100		
0,494	1:3	65	106	158	282	96	102	101	104	4337	A
	1:1,93:3,07	68	104	157	270	100	100	100	100		
0,503	1:3	89	131	217	330	110	108	105	113	4394	A
	1:1,93:3,07	81	121	206	293	100	100	100	100		
0,510	1:3	97	144	237	373	104	105	106	124	4550	M
	1:1,93:3,07	93	137	223	301	100	100	100	100		
0,510	1:3	97	137	214	337	100	104	108	109	4571	A
	1:1,93:3,07	97	132	198	308	100	100	100	100		
0,510	1:3	83	117	183	291	95	103	110	112	4668	A
	1:1,93:3,07	87	114	167	260	100	100	100	100		
0,510	1:3	78	111	186	309	103	97	97	111	4722	A
	1:1,93:3,07	76	115	191	279	100	100	100	100		

testing must undergo considerable change in the near future; the use of fully plastic mortars seems the most promising line of development."

Table 1* summarises the tests made during the last few years by the Institute, and shows the advantage of the new method from this point of view. When applied to finely-ground high-early-strength cements the results were not so satisfactory, as these mortars showed strengths higher than the concretes. In the table are shown only the results with ordinary cements. The fact that the standard sand is made by mixing grains of four different diameters does not seem to complicate the test. The plastic mortar gives satisfactory uniformity even though the mixing of the mortar and filling of the moulds for the test pieces is done by hand. On the other hand it is difficult to obtain a really plastic mortar without segregation of the water with high water-cement ratios when using less than four types of sand.

The method has for its object the determination of mechanical characteristics comparable among themselves and having a practical significance in the field. The essential features of the test are:

(1) Compression test on cylindrical specimens (5 cm. × 10 cm.).

(2) Mortar of 1 : 3 mix, fully plastic, obtained from standard sand resulting from mixing equal parts of the following four types: 0 · 15 mm. to 0 · 30 mm., 0 · 30 mm. to 0 · 60 mm., 0 · 60 mm. to 1 · 20 mm., and 1 · 20 mm. to 1 · 40 mm.

(3) Water content established as a function of a pre-determined mortar consistency to be measured by the flow table (this varies around 0 · 50 litres of water per kg. of cement).

The principal advantages of the proposed method are: (1) The testing of the cement is made under conditions similar to those under which it will be used in practice, namely, a plastic mixture and reasonable water content; (2) For ordinary cements the test yields values comparable with those obtained with concretes having equal water-cement ratios; and (3) In the preparation of the test specimens there is no need for mechanical mixing and tamping.

* Part only of the table is reproduced here (see p.157).

Economies in Fine Grinding.

AN account of the modernisation of the clinker grinding department of one of the works of the Medusa Portland Cement Co. in the United States is given by Mr. Bror Nordberg in a recent number of *Rock Products*. The plant, which uses marl as raw material, is a wet process arrangement. Four of the six 8-ft. by 100-ft. kilns are now in operation, with a combined daily output of 2,000 barrels of clinker. From the kilns, the discharged clinker is passed through 30-ft. rotary coolers, water-sprayed, and is ready for the grinding mills at 140 to 160 deg. F. In the original lay-out, clinker was pulverised by six Kent mills followed by six 5-ft. by 22-ft. tube mills, all in open circuit. Cement was ground in the preliminary mills to about 30 per cent. passing a 200-mesh sieve, and the tube-mill finished product was 89 to 90 per cent. passing a 200-mesh sieve. The capacity of each tube mill was 30 barrels per hour, but the highest specific surface obtainable with reasonable capacity was only 1,450 sq. cm. per gram. Lack of suitable feeders to feed the tube mills uniformly was a drawback.

With the new arrangement the six small preliminary mills have been replaced by two larger Hercules mills, one tube mill has been taken out of service, and the finishing mills are now operated in closed-circuit with air separators. The finish-grinding arrangement is very similar to others used in the cement industry.

A conveyor takes the clinker cooler discharge at 350 deg. F. directly into the preliminary-mill feed-bins. The temperature is rather high as it leaves the cooler, but with the large mill-feed bins and the operation of the clinker grinding department on a 12-hour interval out of each 24 hours, the temperature of the clinker is reduced by the time it enters the mills to between 140 and 160 deg. F.; but the mill output is satisfactory. Each of the bins has a capacity of 600 barrels of clinker, and the gypsum bins combined hold 40 tons.

A partially calcined gypsum is ground with the clinker. This product practically all passes a 24-mesh sieve, and is devoid of moisture. Because of its uniformly fine grains and lack of moisture, it flows evenly from the bins on to the table feeder which is electrically synchronised with the feeder of the Hercules mill.

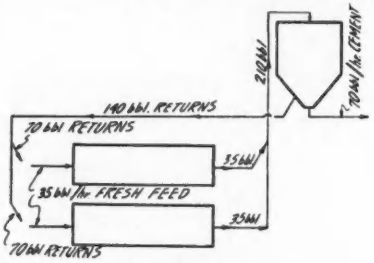
Two preliminary mills have been installed, each driven by a 350-h.p. synchronous motor through couplings. The hourly output through each mill is about 140 barrels passing a 14-mesh screen cloth, with a feed of clinker averaging 140 to 160 deg. F. and oil well temperature as high as 500 deg. F. Fineness of the preliminary mill product is 50 per cent. through a 200-mesh sieve and 68 to 70 per cent. through a 100-mesh sieve.

The preliminary mill discharges to a 16-in. gathering screw conveyor, followed by a bucket elevator, and then to a 16-in. distributor screw conveyor provided with a circular screen which passes it into the tube-mill feed-bins. In addition to the five new hoppers, a sixth, of 135 barrels capacity, serves as a reserve in

the event of short stoppages in the preliminary grinding. Clinker from this bin is then drawn into a horizontal screw conveyor which takes it to the same elevator carrying the Hercules mill product into the various mill-feed bins.

To recover dust and relieve the air pressure in the preliminary mills and the elevator, a bag-type dust collector has been installed. The collector handles 4,100 cu. ft. of air per minute, and has 2,000 sq. ft. of cloth surface. It is a dual unit designed so that one-half of the collector is closed while the other is being shaken down. Recovered dust returns to the screw conveyor handling tube mill feed from the 135-barrel reserve bin passing into the bucket elevator. The tube mills are centre-fed through dog-leg (screw) inclined feeders driven by individual direct current variable-speed motors. The feeder has a speed range of 16 to 32 r.p.m. By this method the feed is readily adjusted and controlled.

Four tube mills are closed-circuited in pairs by bucket elevator and screw conveyor, with two 14-ft. air separators. The air separators are on the mill floor and finished cement as well as tailings discharge to screw conveyors on the



Flow Diagram.

mill room floor. At first some difficulty was experienced because air pressure was being built up within the separators due to the fact that the separators discharged cement directly into the screw conveyor. This arrangement unbalanced the system and it was practically impossible to get a uniform product. By running a duct from the screw conveyor housing into a dust collector, this trouble has been corrected. The two separators discharge into right-hand and left-hand screw conveyors which carry the cement to a chute where it drops to a hopper feeding a Fuller-Kinyon cement conveying system. The duct to the collector is near the point of discharge into the chute. The dust collector is similar to the one used in the preliminary grinding of clinker, and handles dust generated from all sources in the finish grinding.

The tube mills discharge at the centre to 16-in. screw conveyors feeding the common elevator and conveyors into the air separators. Two are operated with one separator in simple circuit, with the tailings returning by screw conveyor and elevator into the trunnion screw which takes the fresh feed from the dog-leg feeder and places it into the mill. The fifth mill can be connected in the circuit in place of either of the others in event of emergency, with proper adjustment of the tailings returns.

The new arrangement is producing about as much cement as before but with a specific surface of 1,600 to 1,700 sq. cm. per gram. Each tube mill produces 35 to 37 barrels of cement per hour. The feed into the separators is 75 to 78 per cent. through a 200-mesh sieve, and the finished product is 90 per cent. through a 325-mesh sieve. The circulating load is 200 per cent., as shown in the accompanying flow diagram. The tube mills operate at 26 r.p.m., and the dog-leg feeder speeds are varied as the tailings increase or decrease. Each mill is charged with $\frac{7}{8}$-in. steel balls to a level 6 in. below the centre line.

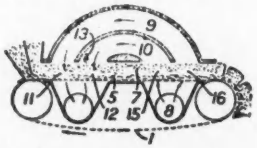
Finished cement is placed in silo storage by a 6-in. Fuller-Kinyon pump with a 5-in. discharge. The pump is a low-pressure unit with an individual rotary compressor which operates at 25 lb. per square inch pressure under normal conditions. The pressure adjusts itself according to load fluctuations on the pump, and the compressor is driven by a 50-h.p. motor through a speed reducer.

Practically all drives in the new mill are direct through cut spiral gears, most of which have a reduction rating of 14·2 : 1. The entire installation represents about 300 h.p. in added connected power, but the actual power demand in kilowatts is about the same as in the old mill. The finish mill and raw grinding departments each has a capacity of 4,000 barrels daily. This is double the kiln capacity, but as a rule the two departments are operated separately.

Recent Patents Relating to Cement.

Cements.

498,837. N. Ahlmann. July 14, 1937.



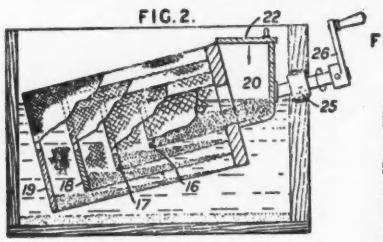
In the burning of cement, a porous layer (7) of the raw material mixed with fuel is deposited upon a travelling grate (1). This layer is dried and preheated in the zone (11) by air which has been heated by passage through the burnt layer at 16 and thereafter the fuel is ignited in the zone (12) by a flame (13) and the burning proper carried on by further air passing downwardly through the layer 7. As shown, the supplies of air for effecting the preheating and the burning respectively are derived from a common source (8) and after passing upwardly through the zones 15 and 16 of the layer 7, are led to the zones 11 and 12 thereof by conduits (9, 10). The grate (1) is protected by a layer 5 of material that has already been burnt.

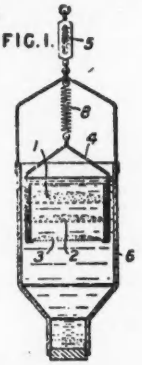
Analysing Concrete.

497,593. Winget, Ltd., and C. W. Stancliffe. June 21, 1937.

A method for the analysis of concrete to enable the proportions of the constituents to be determined comprises washing a sample of the concrete before hardening through a series of sieves of successively decreasing size of mesh so as to separate the sample into portions consisting of cement, sand or fine aggregate, and one or more grades of coarser aggregate respectively.

In the apparatus shown in *Fig.* 1 graded sieves (1, 2, 3) are supported by a cradle (4) and the whole suspended by a spring (8) within a container (6). A known quantity of concrete is placed on the top sieve and the container filled with a known quantity of water. The cradle (4) is agitated so that the grades become separated on the sieves and the cement passes through. The proportions may be estimated by weight or volume. The container may be of glass or transparent material or may comprise a glass window, and may be supported from the balance (5) or from a stand, or may rest on the ground. Means may be provided for raising the sieves above water for weighing purposes.





ANALYSING CONCRETE.

In the apparatus shown in *Fig.* 2 the sample of concrete is introduced into the inner sieve through the chamber (20) and the cover (22) is replaced. The sieves are rotated by the crank (26). After separation the grades are dried and weighed. They may be removed by plugs (16, 17, 18, 19). The fine sand which has passed through the finest sieve may be separated by further washing. The bearing (25) is such as to allow substantially universal movement of the sieves. Either form may be arranged as a battery of units.

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